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EFFECT OF USING DIFFERENT BLENDS OF BIODIESELS ON ENGINE PERFORMANCE AND EXHAUST EMISSION: A REVIEW

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ABSTRACT

In this paper, the effect of biodiesel on engine power, economy, durability and emissions including regulated and non-regulated emissions and the corresponding effect factors are reviewed and analyzed. The use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NOx emission on conventional diesel engines with no or fewer modification. And it favors to reduce carbon deposit and wear of the key engine parts. Therefore, the blends of biodiesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy. However, many further researches about optimization and modification on engine, low temperature performances of engine, new instrumentation and methodology for measurements, etc., should be performed when petroleum diesel is substituted completely by biodiesel.

KEYWORDS: Biodiesel, Diesel Engine, Exhaust Emission, Performance Parameters, Pure Diesel.

INTRODUCTION

The resources of petroleum as fuel are decreasing day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology. With the commercialization of bioenergy, it has provided an effective way to fight against the problem of petroleum scarce and the influence on environment.

Biodiesel, as an alternative fuel of diesel, is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats. It is renewable, biodegradable and oxygenated. Although many researches pointed out that it might help to reduce greenhouse gas emissions, promote sustainable rural development and improve income distribution, there still exist some resistances for using it. The primary cause is a lack of new knowledge about the influence of biodiesel on diesel engines. For example, the reduce of engine power for biodiesel, as well as the increase of fuel consumption, is not as much as anticipated; the early research conclusions have been kept in many people's mind, that is, it is more prone to oxidation for biodiesel which may result in insoluble gums and sediments that can plug fuel filter, and thus it will affect engine durability.

According to analysis and summary in this work, it is helpful for researchers and engine manufacturers to develop the further researches related to optimize and readjust biodiesel engine and its relevant systems and for governments to design new energy policies to impel the use of biodiesel in the light of environmental costs. For private users, this work is helpful to understand profits for using biodiesel and enhance consciousness of environmental protection. Engine performances for biodiesel such as power performance, economy performance and durability are introduced and summarized in this work. Then, the exhaust emissions such as PM (particulate matter), NOx (nitrogen oxides), CO (carbon monoxide), HC (hydrocarbon) and CO_2 are reviewed and summarized.

MATERIALS AND METHODS

1. Effects of Using Different Blends of Biodiesels on Engine Performance and Exhaust Emission

Xue et al [1] did a review study about the effects of using biodiesel on compression ignition engine performance and exhaust emission. Authors investigated that the use of biodiesel leads to the substantial reduction in PM, HC and CO emission accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NO_x emission on conventional diesel engines with no or fewer modification. And it favors to reduce carbon deposit and wear of the key engine parts. Therefore, the blends of biodiesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy. Xue et al investigated the effects of using biodiesel on the following performance parameters and exhaust emission:

Effect of Biodiesel on Engine Power

Xue et al surveyed about 27 literatures to study the effect of pure biodiesel on engine power, and 70.4% of them agreed that, with biodiesel (especially with pure biodiesel), engine power will drop due to the loss of heating value of biodiesel [2-21]. Some authors [2-18] found that the power loss was lower than expected (the loss of heating value of biodiesel compared to diesel) because of power recovery. Utlu and Kocak[6] found that the respective average decrease of torque and power values of WFOME (waste frying oil methyl ester) was 4.3% and 4.5% due to higher viscosity and density and lower heating value (8.8%). Hansen et al. [9] observed that the brake torque loss was 9.1% for B100 biodiesel relative to D2 diesel at 1900 rpm as the results of variation in heating value (13.3%), density and viscosity. Murillo et al. [8] found that the loss of power was 7.14% for biodiesel compared to diesel on a 3-cylinder, naturally aspirated (NA), submarine diesel engine at full load, but the loss of heating value of biodiesel was about 13.5% compared to diesel. The same range between power loss and the decreased heating value was reported by Yucesu et al. [20]. The authors found that the torque and power reduced by 3–6% for pure cotton seeds biodiesel compared to diesel and they claimed that the heating value of biodiesel was less 5% than that of diesel. But they contributed to the difficulties in fuel atomization instead of the loss of heating value.
Lin et al. [21] found that the maximum and minimum differences in engine power and torque at full load between PD (petroleum diesel) and 8 kinds of VOME (vegetable oil methyl ester) fuels were only 1.49% and -0.64%, 1.39% and -1.25%, respectively, due to higher viscosity, higher BSFC (brake specific fuel consumption), higher oxygen content and higher combustion rate of biodiesel.

Effect of Biodiesel on Engine Economy

Armas et al. [22] found that the BSFC of B100 biodiesel, which the LHV (low heating value) was 12.9% lower than that of diesel, had increased approximately 12% compared to diesel on a 2.5 L, DI and TU, common-rail diesel engine operated at 2400rpm and 64Nm. And Hasimoglua et al. [23] obtained the higher BSFC 13% but LHV 13.8% for biodiesel compared to diesel on a 4-cylinder, TU and DI diesel engine. Lin et al. [21] investigated the BSFC of 8 kinds of VOME (vegetable oil methyl ester) on a single-cylinder, 4-stroke, WC, DI diesel engine and found the diesel engine had a higher BSFC in the range of 9.45–14.65% than that of diesel, which was similar to the LHV (12.9–16%) of those VOMEs. Reyes and Sepulveda [11] found that B40 has the minimum SFC (specific fuel consumption) of all the blends (B20, B40, B60, B80 and B100) tested on a 6-cylinder, 4-stroke and WC diesel engine. Ghobadian et al. [24] reported that the mean value of engine SFC of 10%, 20%, 30%, 40% and 50% blends for various engine speeds are 4.0%, 0.8%, 0.6%, −2.2% and 1.4% higher than net diesel fuel respectively.

Effect of Biodiesel on Engine Durability

For durability studies, the aspects to be focused on are carbon deposit, engine wear and problems in fuel system. The overview on durability test for biodiesel and its blends is shown in Table 1.

Table 1: Overview on durability of biodiesel and its blends on engine

S. No.	Content and Feedstock	Reference Diesel	Engine Tested	Operation Conditions	Duration	Test Results	References
1	20% Rice bran oil	Conventional	4-Cylinder, NA, WC, DI	10 nonstop running cycles	100 h	Carbon Deposit (CD): significantly lower; Wear: lower	[25]
2	20% Linseed oil	Agricultural	1-Cylinder, WC, portable	1500 rpm	512 h	Injection (IJ): no choking, no filter plugging; Wear: lower	[26,27]
3	20% Linseed oil	Agricultural	1-Cylinder, WC, portable	1500 rpm	512 h	Wear: lower	[28]
4	100%, 15%, 7.5% palm oil	Conventional	4-Cylinder, NA, WC, IDI, 1.8 L	2000 rpm	100 h	The reduction of wear with the increased content of biodiesel	[29]
5	100%, 50% soybean oil	Conventional	TC, DI, 1.9 L	NEDC driving cycle	1350 km, 750 km	Wear: higher except piston	[30]
6	100% Waste olive oil	Conventional	3-Cylinder, WC, DI, 2.5 L	8-15 kW and 1800-2100 rpm	50 h	CD: no visual difference; Wear: no visual difference	[31]
7	100% rapeseed oil	Conventional	6-cylinder WC, DI, 11L	-	110 h	CD: similar; IJ: cleaner than that of D2	[32]
8	100% Mahua, Karanja oil	High speed diesel	6-cylinder WC, DI, 11L	Static immersion test at ambient temperature	300 D	No corrosion on piston metal and piston liner	[33]

Niraj et al [34] recently conducted the long term endurance test with B40 jatrophha biodiesel in modified engine and with diesel in unmodified engine under similar conditions. Carbon deposition on piston, cylinder and injector were determined for both phases of engine operations. Further, wear of critical engine parts was measured and compared with the help of physical measurement and lubricating oil analysis. The surface analysis with the help of SEM (scanning electron microscopy) and optical micrographs were also carried out. Based on observations and analysis of the study, the following general conclusions were drawn:

i. The reduction in wear with B40 fuel in comparison to that of diesel was in the range of 23–40% for plunger diameter and 11.9–25% for fuel injection needle.
ii. For biodiesel operated engine, wear of piston surface and piston ring were less than that of diesel due to inherent lubricity of biodiesel and optimization of engine parameters. Maximum reduction in wear (58%) was observed at mid location of piston while the weight loss for second compression rings and for oil control ring was recorded around 30% and 8% less for B40 fuelled engine compare to that of diesel fuelled engine.
iii. Very low wear was observed on the cylinder liner and piston with B40 fuelled modified engine compared to that of diesel fuelled engine under similar operating conditions.

Effect of Biodiesel on Exhaust Emission

PM Emission of Biodiesel

Wu et al. [35] investigated the emission performance for five pure biodiesels on a Cummins ISBe6 DI engine with turbocharger and intercooler and found different biodiesels reduced PM emission by 53–69% on average compared with the diesel fuel. Lin et al. [21] also observed that there was significant reduction (ranging from 50% to 72.73%) in the smoke emission for 8 kinds of VOME fuels compared with pure diesel. A small portion of authors found that there was no difference in PM emissions for biodiesel relative to diesel [36,37] or even there was a bit increase [2,22,39–41]. Most of the authors contributed these phenomena to higher viscosity of biodiesel which causes fuel atomization worse and combustion quality deterioration [22, 36, 37, 39–41]. But Armas et al. [38] considered that the increased PM was due to the unburned or partially burned HC emissions. These HC will condense and be absorbed on the PM surface, thus result in the increase of SOF (soluble organic fraction) which is the main component of PM.

NO_x Emission of Biodiesel

Nabi et al. [42] investigated that a maximum of 15% increase in NO_x emissions for B100 was observed at high load condition as the results of 12% oxygen content of the B100 and higher gas temperature in combustion chamber. Ozsezen et al. [4] employed the waste palm oil and canola oil methyl esters (WPOME and COME) on a 6-cylinder DI diesel engine and found that the NO_x emissions of the WPOME and COME increased by 22.13% and 6.48%, respectively. Lin et al. [21] compared 8 kinds of vegetable oil methyl esters (VOME) and observed that using VOME fuels in the diesel engine yielded higher NO_x emissions, ranging from an increase of 5.58% to an increase of 25.97%, when compared to pure diesel. Durbin and Norbeck[43] tested the diesel, pure biodiesel and their blends with 20% biodiesel on four different engines, which represent a large range of heavy-duty engines: TU and NA, DI and IDI. They found a small difference in NO_x emissions and concluded that the difference was not important. Wang et al. [44] drew the same conclusion when they investigated blends with 35% biodiesel from soybean oil and diesel on several vehicles.

CO Emission of Biodiesel

Krahl et al. [45] obtained about 50% reduction in CO emissions for biodiesel from rapeseed oil compared to low and ultra-low sulphur diesel. A higher reduction in CO emissions was shown by Raheman and Phadatare[13], who observed that the reducing range of CO emission was 73–94% for the karanja methyl ester (B100) and its blends (B20, B40, B60 and B80) compared to diesel, and by Ozsezen[4], who found that the CO emissions decreased by 86.89% and 72.68% for WPOME and COME respectively.

HC Emission of Biodiesel

Wu et al. [35] mentioned that the 5 different biodiesels reduced HC emission by 45–67% on average compared with diesel fuel. Puhan et al. [46] reported that the HC emissions reduced average around 63% for biodiesel compared with diesel. Alam et al. [47] found that the HC emissions reduced by 60% for biodiesel regarding ULSD. Lin et al. [21] found the THC emissions reduced in the range of 22.47–33.15% for the 8 kinds of VOMEs. Sahoo et al. [48] compared the biodiesels from jatropha, karanja and polanga and their blends with diesel on a 3-cylinder WC tractor engine during 8 mode cycle tests and reported that HC emissions for the pure biodiesels reduced by 20.73%, 20.64% and 6.75% respectively.

CONCLUSION

Biodiesel, produced from renewable and often domestic sources, represents a more sustainable source of energy and will therefore play an increasingly significant role in providing the energy requirements for transportation. Therefore, more and more researches are focused on the biodiesel engine performances and its emissions in the past 10 years. Although there have always been inconsistent trends for biodiesel engine performances and its emissions due to the different tested engines, the different operating conditions or driving cycles, the different used biodiesel or reference diesel, the different measurement techniques or instruments, etc., the following general conclusions could be drawn according to analysis and summary of the massive related literatures in this work:

i. The use of biodiesel will lead to loss in engine power mainly due to the reduction in heating value of biodiesel compared to diesel, but there exists power recovery for biodiesel engine as the result of an increase in biodiesel fuel consumption. Especially for the blend fuel including a portion of biodiesel, it is not easy for drivers to perceive power losses during practical driving.
ii. An increase in biodiesel fuel consumption, due to low heatingvalue and high density and viscosity of biodiesel, has beenfound, but this trend will be weakened as the proportion ofbiodiesel reduces in the blend.
iii. It can be concluded from the limited literatures that the useof biodiesel favors to reduce carbon deposit and wear of thekey engine parts, compared with diesel. It is attributed to thelower soot formation, which is consistent to the reduced PMemissions of biodiesel and the inherent lubricity of biodiesel.
iv. The majority of studies have shown that PM emissions forbiodiesel are significantly reduced, compared with diesel. Thehigher oxygen content and lower aromatic compounds hasbeen regarded as the main reasons.
v. The vast majority of literatures agree that NOx emissions willincrease when using biodiesel. This increase is mainly dueto higher oxygen content for biodiesel. Moreover, the cetanenumber and different injection characteristics also have animpact on NOx emissions for biodiesel.
vi. It is accepted commonly that CO emissions reduce when usingbiodiesel due to the higher oxygen content and the lower carbonto hydrogen ratio in biodiesel compared to diesel.
vii. It is predominant viewpoint that HC emissions reduce whenbiodiesel is fueled instead of diesel. This reduction is mainlycontributed to the higher oxygen content of biodiesel, but theadvance in injection and combustion of biodiesel also favorthe lower THC emissions.
viii. There exist the inconsistent conclusions, some researches indicated that the CO_2 emission reduces for biodiesel as a result of the low carbon to hydrocarbons ratio and some researches showed that the CO_2 emission increases or keeps similar because of more effective combustion. But in any event, the CO_2 emission of biodiesel reduces greatly from the view of the life cycle circulation of CO_2.
ix. Most of researches showed that aromatic and poly-aromatic compounds emissions for biodiesel reduce with regard to diesel. Carbonylcompounds emissions have discordant results for biodiesel, although it is widely accepted that, biodiesel increases these oxidants emissions because of higher oxygen content.
x. It can be concluded that the blends of biodiesel with small content by volume could replace diesel in order to help in controlling air pollution and easing the pressure on scarce resources to a great extent without significantly sacrificing engine power and economy.

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